Response to Comments by Anonymous Reviewer #1

The impact of selected reference period on drought characteristics quantification is investigated in this paper. This is an interesting research question since the reference period matters under climate change. My major comment is that the research question is diluted many other factors (complexity) in the paper, e.g., two data sets (CRU and UDEL) and different regions. I encourage the authors to focus on the main research question (i.e., the impact of selected reference period on drought characteristics) and provide more insights on the reference period selection. For example, if climate is stationary, does the selected reference period matter? If the reference period is dry, are the quantified drought characteristics more severe in the assessment period?

>> As suggested by the reviewer, we have performed additional analyses to provide further insight regarding the reference period selection while still providing the results from the multiple datasets and regions.

(1) We investigated how the precipitation and temperature trends are related to the SPEI trend based on the reference period to improve the understanding of the role of the selected reference period in a stationary climate.

Based on the grid-level trend analyses of precipitation, air temperature and SPEI-12, we categorize each grid cell based on increasing, decreasing or neutral trends for each variable (i.e., precipitation, air temperature and SPEI-12). For SPEI-12, increasing and decreasing trends represent wetting and drying trends. For 27 (3*3*3) different cases, we present the ratio of each case relative to the total number of cases (i.e., total number of effective grid cells in all four regions), as shown in the figure below.

First, the SPEI-12 trends are the same between Ref1 and Ref3, as the estimation periods share the one reference period in both Ref1 and Ref3 while each estimation period uses its own reference period in Ref2. Thus, the values of SPEI-12 are different in both cases, but the trends (i.e., relative values) are the same. Second, precipitation and air temperature exhibit neutral (or no) trends (in the center panel; presumably stationary climate), and the grid percentages of different trends in SPEI-12 vary between Ref1/Ref3 and Ref2. However, the ratio is relatively small, as most grid cells display increasing temperature trends. Finally, based on neutral precipitation and increasing air temperature trends in most grid cells, the numbers of cells with neutral and drying SPEI-12 trends are notably different between Ref1/Ref3 and Ref2. An increasing temperature trend can be observed in most regions; thus, it is important to consider its impact on SPEI.

We will add this figure and a related explanation to the revised manuscript at the end of section 3.2.



(b) UDEL

Figure. The SPEI trends with 12-month lag (SPEI12) for three different reference periods (Ref1 to Ref3) for the CRU and UDEL datasets based on the trends of monthly precipitation and temperature in the four zones

(2) To understand how the drought characteristics would change if the reference period is dry (the question the reviewer asked), we compare the drought area (%) for dry and wet cases in EA, EU, US and WA with defining dry and wet cases as below. We define the drought and wet cases with using a water surplus or deficit D (in Eq. (1), D=P-PET). We compare Ds between the reference period and estimation period. A value of D in the estimation period less than that in the reference period represents the dry case, i.e., the estimation period is drier than the reference period.

We perform such analyses only in Ref1 for estimation periods of 1901-1957 (P1) and 1958-2014 (P2) and a reference/calibration period from 1901-2014 (P1+P2). For dry and wet cases, we quantify the drought areas (%) according to the three different drought levels (D1, D2 and D3, which denote the cases of SPEI < -1.0, SPEI < -2.0 and SPEI < -3.0, respectively) in the four regions.

We first compare the monthly average Ds values between the estimation period and calibration period. The average D in P1 or P2 (estimation period) is smaller than that in P1+P2 (reference period), and it is considered to be the dry case. For example, in EA, the Ds values in P2 and P1+P2 are -4.89 mm/month and -5.07 mm/month, respectively; thus, it is a dry case. Then, for each case, the drought areas are analyzed as shown in the figure below. As a result, the drought area tends to be larger in the dry case than that in the wet case in most regions, particularly in West Africa. However, we also note there are a few exceptions, which may be attributed to the fact that we use the regional average Ds. Thus, we cannot consider the grid-level variability in Ds.

We will add this figure and related explanation to the revised manuscript at the end of section 3.3.

	CRU			UDEL		
	P1	P2	P1+P2	P1	P2	P1+P2
EA	-4.29	-5.85	-5.07	-3.40	-5.03	-4.21
EU	7.32	7.21	7.26	5.92	5.91	5.92
US	-1.09	0.64	-0.23	-0.75	1.13	0.19
WA	-99.26	-111.23	-105.24	-101.17	-114.01	-107.59

Table. Monthly average D (mm/month) in four zones (EA, EU, US and WA) for two datasets (CRU and UDEL)



Figure. Averaged drought areas in dry and wet cases in four study regions according to the drought magnitudes of D1, D2 and D3 for two datasets (CRU and UDEL)

The authors may provide some suggestions/comments on the selection of reference period in practice? For example, is the early period or entire period of historical data recommend for the reference period? Or the author may provide a guideline to select reference period, e.g., the first step is to quantify the existence of trend in climate variables etc.

>> We agree with your suggestion regarding the practical selection of a reference period. However, this study focuses on how the selection of a reference period affects drought characteristics, rather the selection process. Thus, we will add the following text to the conclusion:

"Our results suggest that it is necessary to quantify the trends of climate variables such as precipitation and air temperature as the first step in selecting a reference period."

This statement is consistent with our finding that the SPEI trends differ in response to the trends of climate variables, particularly that of air temperature, as noted in the above results.

The number of figures can be reduced.

>> We find that all figures are necessary to understand the impacts of the reference periods on SPEI-12. Nonetheless, it would be possible to move a few figures, such as Fig. 1, to the appendix.

Line 16 on page 2: rephrase the sentence: "They found that local regions"

>> As noted by the reviewer, we will revise the manuscript as follows: "The degrees of increasing drought frequency and intensity varied with the stations in the study region."

Line 35 on page 3 - Line 7 on page 4: The index and equations are difficult to follow due to the confusing indexes. For example, i is used for month index in line 35 on page 3; but it is used for year index in line 3 on page 4.

>> In the revised manuscript, we will use j for the month in line 35 on page 3 to avoid any confusion:

"Step 1: Estimate the water surplus or deficit in month j (D_j) based on the difference between precipitation (P_j) and potential evapotranspiration (PET_j): $D_j = P_j - PET_j$."

Line 34 on page 8 – line 2 on page 9: Are these finding specific to this study or general to any regions and time periods?

>> As such findings were only confirmed for two datasets (CRU and UDEL), we will revise this sentence as follows:

"Furthermore, we find that the reference periods influence the assessment of drought characteristics, particularly the severity and spatial extent, based on the two datasets."

Line 26 page 1: change "hazard" to "hazards"? >> This correction will be made in the revised manuscript.

Line 31 on page 1: "state" to "stated"? >> This correction will be made in the revised manuscript.

Line 32 on page 1: "witnessed" to "have been witnessed"? >> This correction will be made in the revised manuscript.

Line 12 on page 4: "it one of" to "it is one of" >> This correction will be made in the revised manuscript.

Lines 24-29 on page 4: please correct the indexes for equations, e.g., equation (1) on page 4 should be equation (5). >> This correction will be made in the revised manuscript.

Lines 10 on page 5: change "relative to" to "and" >> This correction will be made in the revised manuscript.